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The Effects of Elevated Shoe Heights on Static and Dynamic Balance in Healthy Younger Women

Kip S. Ouchi
University of North Dakota

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THE EFFECTS OF ELEVATED SHOE HEIGHTS
ON STATIC AND DYNAMIC BALANCE
IN HEALTHY YOUNGER WOMEN

by

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An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

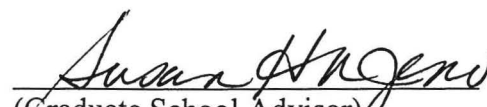
Grand Forks, North Dakota


May
2001



This Independent Study, submitted by Kip S. Ouchi, in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.


(Faculty Preceptor)


(Graduate School Advisor)


(Chairperson, Physical Therapy)

PERMISSION

Title The Effects of Elevated Shoe Heights on Static and Dynamic Balance in Healthy Younger Women

Department Physical Therapy

Degree Master of Physical Therapy

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ABSTRACT

The purpose of this study was to determine the effects of elevated shoe heights on static and dynamic balance in healthy young women. The balance of 30 female volunteer subjects with ages ranging from 20 to 26 years (mean age = 22.3 years) was tested. Dynamic balance was tested using the limits of stability (LOS) test on the NeuroCom[®] Balance Master (NBM[®]), version 6.1 as well as the Functional Reach Test (FRT). Each subject's static balance was tested using the bilateral stance test on the NBM[®]. Subjects participated in a one time testing session which consisted of the performance of the three balance tests in a random order with elevated-soled shoes on (minimum heel height of 4.0 cm) and barefoot.

Significant differences in dynamic stability were noted in the LOS test and in the FRT. The results of the two dynamic tests suggest that balance may be impaired with the wearing of shoes with elevated soles. The bilateral stance test for static stability found that subjects exhibited increased postural sway when barefoot as compared to with elevated-soled shoes on. The results of this static test suggest that stationary balance may be somewhat more stable with elevated shoe wear.

The findings of the LOS test and FRT are in agreement with much of the previous high-heeled shoe literature, however, the bilateral stance test for postural sway is not in agreement with some of the previous research. Nonetheless, it is apparent that elevated

shoe heights can produce dynamic balance deficits and therefore clinicians should always carefully inspect and assess a clients footwear as part of the evaluation procedure.

CHAPTER I

INTRODUCTION/LITERATURE REVIEW

The effects of footwear, particularly those with higher heel heights, on the human body has been a topic of much investigation by researchers in recent years. Many studies have looked specifically at the effects of varying heel heights on posture,¹⁻⁵ joint kinematics during gait,^{4,6-8} foot position awareness,^{9,10} foot function,¹¹⁻¹³ and energy cost of walking⁶ to name a few areas. However, there is a rather limited body of research that has studied the effects of shoes of varying heel heights on static and dynamic balance.

A better understanding of the effect that higher-heeled or elevated-soled shoes have on balance is especially important since it is common in today's society for women to wear these types of shoes in both professional and social settings.⁶ The relative safety and potential risk of injury that these shoes pose to the wearer have long been a concern for many healthcare professionals.¹⁴ This is especially true in Japan where the latest fashion trends have seen a rebirth of the platform-style shoes made famous in the 1970's. In fact, in Japan, an industry survey found that 40% of women in their 20's and 25% of women in their 30's already own at least one pair of platform-type shoes¹⁵ and that sales of platform shoes in Japan are estimated to be \$100 million a year.¹⁶ However, popularity aside, it is the safety of these shoes which has received much media attention over the last two years. *The New York Times* reported recently that the Japan Consumer Center issued a public warning about the dangers of platform shoes.¹⁷ This warning as

well as some tips on how to avoid injuries were in lieu of a string of recent accidents and deaths including ailments ranging from sprained ankles and broken bones to fatal traffic accidents and fractured skulls from falls where platform shoes were implicated as the cause. Alarming, one recent poll in Japan found that 23% of wearers had fallen while donning platforms, with nearly half of those women suffering an injury.¹⁷ Not surprisingly concerns about lawsuits have prompted Japanese shoe manufacturers to attach warning labels to the shoes.

Safety regarding footwear, however, is not something new. Proper footwear has long been an issue of major concern for clinicians working with the elderly population.^{18,19} This is because researchers have pointed to inappropriate footwear as being one of the main extrinsic factors that contributes to falls in older individuals.^{1,19-21} In fact, it has been noted by community based studies that approximately one-third of people 65 years or older will experience a fall within any given year.^{1,19} This natural propensity towards falls in the elderly has been linked to the deterioration of peripheral sensory function with age.²² However, some researchers have recently shown that certain behavioral and environmental factors (e.g., footwear) factors have a greater affect on stability than aging.¹⁸

These findings have in turn led to more research regarding the effects that different shoe characteristics have on balance in the elderly.^{18,23} Robbins and Waked²⁴ found that choice of footwear can influence stability greatly and that when comparing hard-soled shoes to modern athletic and walking shoes, the latter two can increase sway velocity by greater than 300%. In a similar study by Lord et al,²³ the affect of shoe collar height and sole hardness was researched. Forty-two women aged 60 to 92 years

underwent assessments of static (body sway) and dynamic (maximal balance range and coordinated stability) under five footwear conditions ranging from wearing soft-soled bowls shoes to barefoot. Results showed that subjects had better balance when wearing shoes with higher collars than when wearing shoes with low collars, and that sole hardness was not related to balance.

In an earlier study by Lord and Bashford,²⁵ thirty women, 60 to 89 years old, underwent assessments of static and dynamic balance to determine whether shoe characteristics affect balance in older women. Each subject was tested under four conditions: 1) barefoot, 2) in standard low-heeled shoes, 3) in standard high-heeled shoes, and 4) in their own shoes. Statistical analysis (MANOVA) showed a significant condition effect where subjects performed best in bare feet or low-heeled shoes and worst in high-heeled shoes. These findings led the researchers to conclude that balance is maximized when barefoot or wearing walking shoes, whereas high-heeled shoes constitute an avoidable balance hazard for older women.

The effect of shoes with elevated heel heights on balance in older women were most recently investigated by Arnadottir and Mercer.²⁶ In their study, thirty-five women aged 65 to 93 years were tested with the Functional Reach Test (FRT), Timed Up and Go Test (TUG), and 10-Meter Walk Test (TMW) under three separate footwear conditions: 1) while wearing walking shoes, 2) wearing dress shoes, and 3) barefooted. A little over half of the subjects performed the FRT and TUG on a linoleum floor with the remainder performing those tests on a firm, low-pile, carpeted floor. The TMW was administered to all 35 subjects on a firm, low-pile, carpeted floor. The results of this study showed that regardless of floor surface, subjects performed better on the FRT when barefooted or

wearing walking shoes compared with when they wore dress shoes (minimum heel height of 1.6 in). Differences were also found for all footwear conditions for the TUG performed on linoleum floor and for the TMW. The researchers noted that for these tests the women moved fastest in walking shoes, followed by the barefooted condition and slowest wearing dress shoes. Based on the results, it was concluded that footwear intervention may improve performance of gait and balance tasks by older women and that the type of footwear should always be documented and kept constant when utilizing the aforementioned clinical test measures.

As evidenced by the growing body of research regarding the effects that high-heeled shoes have on the human body, it appears to be quite clear that these styles of shoes pose a definite and real health risk to those who wear them, particularly older women. However, in lieu of the recent safety outcry in Japan over the hazards of wearing trendy platform shoes, a reexamination of the effects that these types of shoes have on the static and dynamic balance of a younger population appears to be warranted. This is particularly true with the evolution of women shoe fashion away from the high-incline spiked heels that are described in much of the high-heel research literature, toward elevated platform-type shoes that raise the entire foot, not just the heel, two to three inches.¹⁴ Today's elevated-soled shoes also commonly have a more clunky wider based heel which is in stark contrast to the high-incline spiked heeled shoes which have relatively modest surface areas under the heel. With the growing popularity of this style of shoe in women's fashion, particularly in young women, and the documented health risks they appear to pose,^{14,17} the effect of elevated sole heights with wider based heels on

static and dynamic balance in 30 young women ages 20-29 years old was chosen for this investigation.

Many assessment instruments have been developed and validated, focusing on different aspects of physical performance.²⁶ And, it has been the goal of researchers and clinicians alike to design instruments that provide objective measurements of physical impairments or functional limitations, for screening, evaluation, monitoring changes, and predicting outcomes for individuals and populations. For the purpose of this study, instruments that had proven reliability, were readily available, and that were valid instruments for measuring postural control as it relates to both static and dynamic balance were selected. Based on subject criterion requirements and the availability of equipment the NeuroCom® Balance Master (NBM®) and FRT were deemed the instruments of choice for evaluation.

Despite the general lack of research regarding the various platform systems currently being utilized for assessment and training, the NBM® system has been proven to have moderate to high reliability in the limited number of studies that have been conducted.²⁷ Liston et al²⁸ examined the reliability of dynamic balance tests available on the NBM® by testing stroke patients with a randomized version of the 75% limits of stability (LOS) test. The LOS test was administered to a sample of hemiparetic patients on three separate occasions one week apart. They found the movement variables, movement time and path sway to be strongly reliable ($ICC [2,1] = .88$ and $.84$ respectively). In a similar study conducted by Clark et al,²⁹ the reliability of the LOS test and determination of the relative variance contributions from identified sources of error was investigated. Thirty-eight community dwelling healthy older adults with no recent

history of falls performed the LOS test at 75% and 100% of their theoretical LOS using the Pro Balance Master System[®] on three consecutive days. Their results showed that estimated generalizability coefficients for two and three days of testing ranged from .69 to .91 and that relative contributions of the day facet were small. They also found that there was no significant differences (RM ANOVA) for the movement variables: movement velocity (MV), maximum center of gravity (COG) excursion (ME), and end point COG excursion (EE) observed across the three days. From these results the researchers concluded that when testing healthy older adults with no recent history of falls the 75% and 100% LOS tests are reliable tests of dynamic balance. They also concluded that dynamic balance measures were generally consistent across multiple evaluations. It should be noted, however, that according to Clark et al,²⁹ direct comparisons of their results to previous studies²⁸ on test-retest reliability of LOS movement variables are not possible. This is because the movement variables used by the NBM[®] software (version 5.0b) in their study, differs from the original movement variables for the LOS test (i.e., movement time, path sway, target sway, and distance error) used in previous investigations.

In addition to providing reliable measurements regarding dynamic balance (i.e., LOS tests), force platform systems (e.g., NBM[®] system) have advantages in objectively quantifying body sway and measuring the location of an individual's center of pressure related to the base-of-support (BOS).²⁷ Hageman et al²⁷ used body sway area under conditions of eyes open, eyes closed, and with visual feedback using the NBM[®] system as one of their main outcome measures. Hageman and colleagues²⁷ pilot study was conducted on twelve volunteers ages 24 to 68 years with interclass correlation

coefficients (ICC's) revealing high test-retest reliability for NBM[®] measures of sway area with eyes open [ICC (3,4) = .91], sway area with eyes closed [ICC (3,4) = .97], and sway area with visual feedback [ICC (3,4) = .94] with subjects being measured one week apart. The results of their actual study showed that age was found to have a significant effect on all three conditions of sway area. Furthermore, the results that postural sway increases with age was consistent with previous findings on standing body sway using other systems and measurement techniques.³⁰

In addition to the NBM[®] 100% LOS test, the Functional Reach Test (FRT) was chosen as a second assessment instrument for dynamic balance. This is because the FRT also captures the ability to control movement over a fixed base of support.³¹ The FRT, as first described by Duncan et al,³¹ has been shown to have good criterion validity,³² predictive validity,³³ test-retest reliability,^{33,34} and inter-observer reliability³⁴ for younger and older adults. It is also a safe, inexpensive, and easy test to administer.²⁶

Taking a more in depth look into some of the reliability studies done on the FRT, Duncan et al³¹ conducted a study using the FRT with 217 elderly male veterans (aged 70-104 years) which showed that the test provides very reliable measurements of balance and that it can also be used to predict the risk of falling. In another study by Duncan and colleagues,³³ the FRT demonstrated excellent test-retest reliability with an ICC = .92 when studying FRT scores correlated with center of pressure excursion in a sample of 128 community volunteers aged 20 to 87 years. Furthermore, Weiner et al³⁶ found that the FRT demonstrated concurrent validity as a marker of physical frailty when examining the relationship between FRT and other physical performance measures (e.g., mobility skills protocol, physical activities of daily living, instrumental activities of daily living) in

the frail elderly. The FRT has also been reported, by Weiner et al,³⁵ in another study to demonstrate sensitivity to change in balance in inpatient male veterans undergoing physical rehabilitation. In addition, Light et al³² concluded as a result of their finding of good criterion related validity with the FRT that carefully trained clinicians are capable of reading the functional reach measurement on a yardstick to within ½ inch and that these readings correlate highly to those of videotape analysis (ICC = .86).

Purpose

The purpose of this study was to determine if significant changes occur in static (bilateral stance test) and dynamic (LOS test and FRT) balance in healthy young women (ages 20-29 years) when the same individual is assessed barefoot and while wearing elevated-soled shoes on the NBM[®] (version 6.1) and during the Functional Reach Test. The research questions that will be addressed are: 1) Is there a significant difference in measures of static balance when the same individual is assessed barefoot as compared to while wearing elevated-soled shoes? and, 2) Is there a significant difference in measures of dynamic balance when the same individual is assessed barefoot as compared to while wearing elevated-soled shoes?

It is hypothesized that there will be a significant decrease in static balance when comparing the barefoot condition to the elevated-soled shoe condition. The null hypothesis is that there will be no significant decrease in static balance when comparing the barefoot condition to the elevated-soled shoe condition. It is also hypothesized that there will be a significant decrease in dynamic balance when comparing the barefoot condition to the elevated-soled shoe condition. The null hypothesis in this case is that

there will be no significant difference in dynamic balance when comparing the barefoot condition to the elevated-soled shoe condition.

Clinical application

Balance is an essential component to carrying out all activities of daily living. Extrinsic factors such as footwear may significantly affect balance and put individuals at risk for injury. This study has the potential for many benefits to individual participants, society, and the medical community. Through assessment using the NBM[®] and FRT, participants will learn about the relative safety of their own dress/casual shoes. Data results may help provide physical therapists and other healthcare professionals with evidence based research to assist in proper shoe recommendations for clients and/or aid in activity selection for those involved in dynamic balance while wearing higher-soled shoes. This could in turn help decrease the risk of injuries occurring secondary to loss of balance created by inappropriate footwear. Finally, this study can be used as a basis for future research involving a larger sample size and/or different shoe types.

CHAPTER II

METHODOLOGY

The final approval for this study was obtained from the University of North Dakota (UND) Institutional Review Board for the use of human subjects. A copy of the Human Subjects Review form is located in Appendix A. During recruitment, all individuals were informed that their participation was strictly voluntary. The components of the study were explained to those interested in participating, with each subject giving informed written consent. A copy of this consent form is located in Appendix B. To identify possible health or safety concerns, as well as to gather individual shoe information from participants, a health background and shoe history questionnaire was given to each individual before inclusion. This questionnaire was utilized to obtain information including: medications, past injuries/vestibular problems, vision, exercise level, shoe size, frequency of wear, activity level in shoes, orthotic use, as well as others. A copy of this questionnaire is located in Appendix C.

Subjects

In order to test the hypotheses associated with this study, 31 healthy women within the age range of 20-39 years were recruited from two physical therapy classes within the UND student population. It was determined prior to testing that subjects must meet the following inclusion criteria prior to participation in this study.

1. No current or past medical diagnosis or history affecting balance.

2. Currently taking no medications affecting the central nervous system (CNS) or medications known to affect balance/coordination.
3. No symptoms of dizziness or lightheadedness.
4. Have no symptoms suggestive of vestibular or neurologic disorders.
5. No psychological disorders including depression.
6. No history of two or more unexplained falls within the past 6 months.
7. Normal vision with or without glasses.
8. Will own a pair of dress/casual shoes with a heel height of at least 4 cm (1.6 inches).
9. Each subject will have worn these elevated shoes at a frequency of at least once a week.

Once all components of the criteria were met, and a signed consent form was received, each individual was tested on the NeuroCom[®] Balance Master and Functional Reach Test in a randomized order.

Instrumentation

The NeuroCom[®] Balance Master (NeuroCom[®] International, Inc, 9570 SE Lawnfield Road, Clackamas, OR 97015-9611, Telephone (800) 767-6744) was used in this study to assess the limits of stability and to assess postural sway using the bilateral stance test. The machine is composed of two 9-inch by 60-inch force platforms resting on four load cells which transfer information from the platform system to a connected computer.³⁸ A picture of the NBM[®] in use can be seen in Figure 1. This computerized system is integrated with a software program that interprets various data obtained during a balance assessment. This provides quantitative data and provides an objective measure

of balance and balance-related activities to the researcher and subject by giving continuing visual feedback and statistical information regarding performance.³⁹ Performance information is available on computerized printouts which can be depicted as numerical charts, graphs, and picture representations of the assessment with tracing of the center-of-gravity movement. An example of a computer results sheet can be seen in Appendix D.

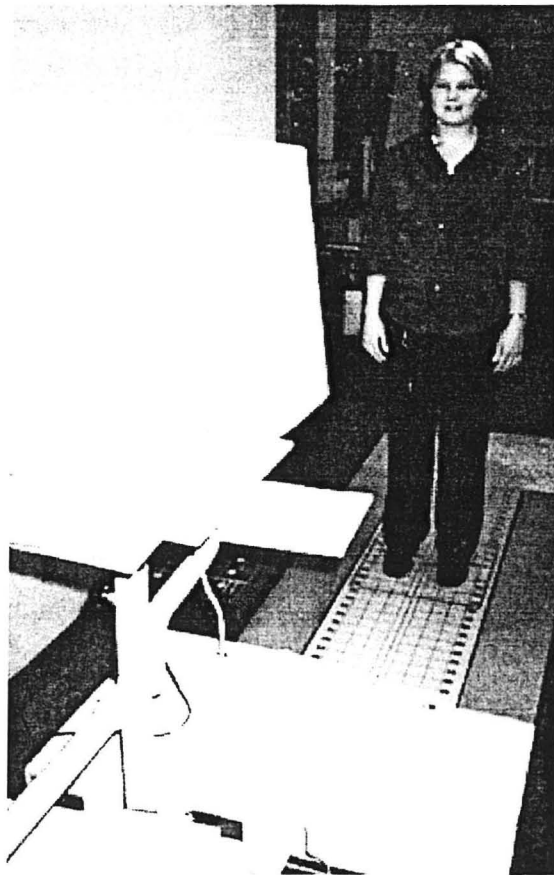


Figure 1. NeuroCom[®] Balance Master.

Limits of Stability Test

The limits of stability test, quantifies several movement characteristics associated with the subjects ability to sway voluntarily to various locations in space and maintain stability at these positions for a brief period of time.³⁸ This test is used to assess reaction time, movement velocity, endpoint excursion, directional control, and maximum excursion. The subjects are required to lean in eight directions, as far as possible without losing their balance or taking a step. These directions include: forward, forward-right, right, right-back, back, back-left, and left-forward. Scores for each direction (e.g., back, back-right, and back-left) are combined in a weighted fashion to obtain an overall value for that direction (e.g., back). For example:

$$\frac{(.8)(\text{left-back}) + (.8)(\text{right-back}) + (1)(\text{back})}{2.6}$$

During the testing, the location of the subjects COG is displayed on the computer screen as a man-like cursor which provides visual feedback. By weight-shifting, the subject is required to lean as quickly and accurately as possible so that the cursor coincides with targets that are also displayed on the screen. Refer to the NeuroCom[®] Balance Master manual for further information.³⁸ The following list describes the five components which the LOS tests:

1. Reaction time—time in seconds between the cue to move and the initiation of movement.
2. Movement velocity—the average speed of COG movement, expressed in degrees per second, between 5% and 95% of the distance to the primary endpoint.

3. Endpoint Excursion—on the primary attempt to reach the target, it is the distance traveled by the COG. This is expressed in % LOS and is considered to be the point at which the initial movement toward the target ceases, and subsequent corrective movement begins.
4. Maximal Excursion—the furthest distance traveled by the COG during the trial.
5. Directional Control—the amount of movement in the intended direction (toward the target) compared to the amount of extraneous movement (away from the target). This is calculated as a percentage in the following manner:

$$\frac{(\text{amount of intended movement}) - (\text{amount of extraneous movement})}{\text{amount of intended movement}}$$

For example, if a subject's movement is directly toward the target in a straight line, then the amount of extraneous movement would equal zero, and the perfect directional control score would be 100%.

Bilateral Stance Test

A bilateral stance test on a firm surface was also used in this study and involved static standing in a predetermined area on the force plates, depending on the subjects' height. This test was used to quantify postural sway velocity and determine COG position with the subject standing quietly on the force plate with eyes open. The relative absence of COG sway is indicated as stability, while greater sway indicates less stability. The average COG sway was computed in the computer and quantified for data interpretation.

Functional Reach Test

The Functional Reach Test, as first described by Duncan et al,³¹ was utilized as a second test of dynamic balance. This test is used to assess the maximal distance an individual can reach forward beyond arm's length while maintaining a fixed base of support in the standing position.³⁴ The testing equipment consisted of a 48 inch leveled measuring stick mounted on the wall at the shoulder height of the subject. Tape was placed on the ground as a reference point for each subject to start from. The distance reached in centimeters was recorded and the mean of three trials was computed.

Assessment Procedure

Subjects reported to the research room on the second floor of the UND Physical Therapy Department for assessment on the NBM[®] and FRT. Before assessment individuals randomly selected the order of tests (i.e., bilateral stance, LOS, FRT) to be performed and whether to begin testing with their elevated shoes on or off. Once the order of tests and initial shoe condition were determined, all three tests were performed. One researcher was responsible for the bilateral stance and LOS testing on the NBM[®], while another researcher was responsible for testing of the Functional Reach Test. Before assessment on the NBM[®], individuals were assigned an identification number and their date of birth and height were entered in the file. All tests were administered at the subject's pace in order to provide adequate warm-up and rest between trials. One researcher was also assigned the task of measuring the dimensions of all elevated shoes either before or after testing for consistency of measurements. Shoe dimensions measured included: length of heel, width of heel, sole thickness beneath the first metatarsal height (i.e. forefoot height), and vertical height at back of heel. Figure 2

represents measurements taken. See Appendix E for pictures of the different elevated shoe designs.

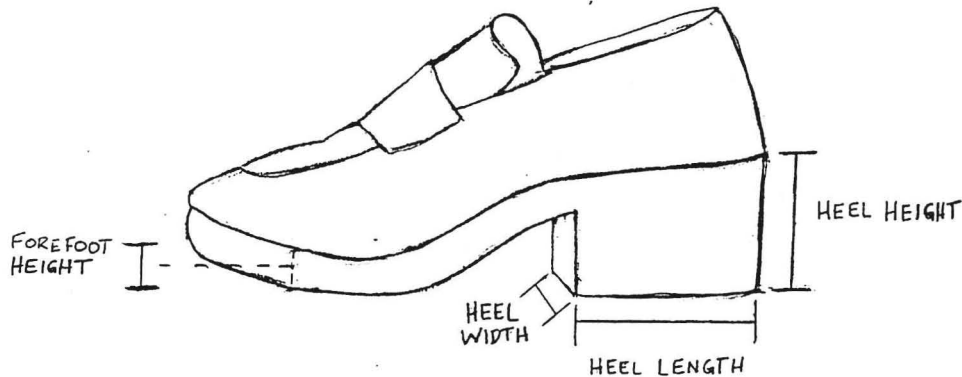


Figure 2. Elevated shoe measurements, taken in centimeters.

Limits of Stability Test

Prior to testing, each subject was introduced to the force platform system. This included a general description of the apparatus and how performance would be measured, balance strategies utilized to maintain balance, subject expectations, and a warm-up session. Subject data was entered into the file consisting of an identification number, date of birth, and height. Each subject was instructed in and positioned for proper foot placement on the force plates as per NBM[®] protocol. Figure 3 shows the correct foot placement used. See the NeuroCom[®] Balance Master manual for specific details.³⁸

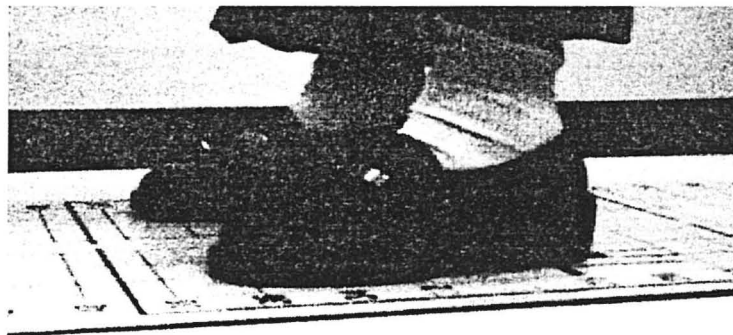


Figure 3. NBM[®] foot placement used.

During testing, the subject was instructed to maintain the foot position while being able to splay the forefoot and lift the toes to maintain balance. The balls of the feet and heels had to remain in contact with the force plate at all times or testing would be repeated.

Prior to testing, each subject performed a warm-up on the NBM[®] which consisted of weight shifting to 100% LOS. The subject was instructed to lean in all eight directions (Figure 4) in the same order as the testing would be administered. Each target was to be reached as quickly and accurately as possible as soon as the green “GO” indicator appeared on the bottom of the screen. This position was then held until the cursor disappeared, followed by movement back to the center of the screen.

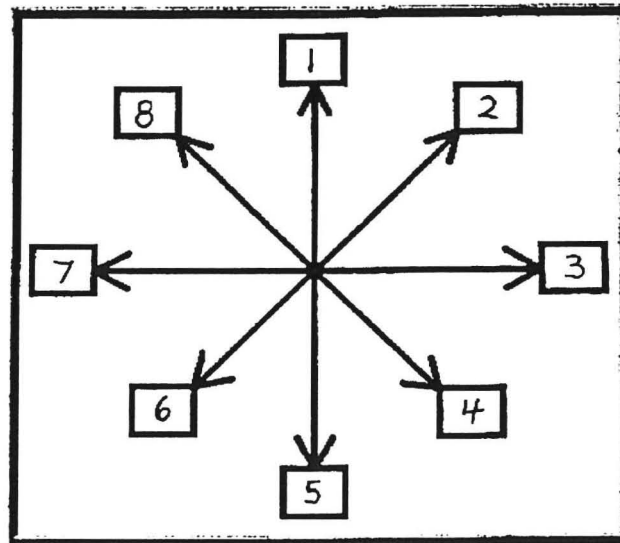


Figure 4. Eight directions of limits of stability.

A complete set of verbal instructions administered to each subject prior to testing can be found in Appendix F. Subjects were allowed to bend at the knees and hips and use their arms for balance, as long as their feet maintained contact with the force plate in the manner described above. Each subject was allowed to warm-up for as long as desired

in order to feel as though able to adequately and comfortably perform the test. Following completion of one entire warm-up target set, the subject then performed the testing procedure. An adequate practice session is important since Hamman et al⁴⁰ determined that there is a high "learning curve" associated with using the NBM[®]. In their study which examined the training effects during repeated training sessions using the NBM[®], they observed statistically significant improvements in normal, healthy subjects' test results after repeated training sessions.

Bilateral Stance Test

The bilateral stance test on a firm surface used in this study involved static standing in a predetermined area on the force plates of the NBM[®]. Each subject stood for 3 trials with each trial lasting 10 seconds. Subjects were told to stand as upright and as steady as possible during testing. A complete set of instructions given to each subject prior to testing can be found in Appendix F.

Functional Reach Test

The Functional Reach Test was also used to assess dynamic stability. Each subject was asked to stand with the distal ends of each great toe (or front edge of shoes) at the edge of the tape-line and with their feet shoulder-width apart. Subjects were also asked to stand with their dominant arm as close to the wall as possible (i.e., ~ 3 inches) without touching the wall. The same standing position was used for all trials. Subjects were told to make a fist with their dominant hand and raise their arm forward to a 90° angle so that it was parallel to the measuring stick mounted on the wall. From this position, a starting measurement was taken at the third metacarpal of the subject's dominant hand. When assuming the starting position, subjects were instructed not to

protract or retract their scapula; their position was then inspected to confirm a correct starting position. The subject was then asked to “reach as far forward as possible with your arm without losing your balance or taking a step.” Guidelines given to subjects prior to reaching were to: keep the reaching arm parallel with the measuring stick mounted on the wall, avoid touching the wall while reaching, not twist the upper body while reaching, and not to lift their heels off of the floor at any time. The final reaching position was recorded in the same fashion as the starting position. The distance reached in centimeters was recorded and the mean of three trials was computed. If during any trial, the base of support was moved (e.g., step taken), or, any of the guidelines were violated the trial was discarded and repeated. A complete listing of the verbal instructions given to subjects can be found in Appendix G. A spotter was present during all testing as the task was performed. Prior to testing, each subject received two practice trials and all questions regarding the testing were answered. Each subject performed the test with shoes on and barefoot.

Pilot Study

A pilot study on the NBM[®] was performed in order to establish intrarater (test-retest) reliability for one of the testers. A separate pilot study was also performed using the same subjects on the Functional Reach Test in order to establish intrarater reliability of another tester. Ten subjects ranging in age from 20-50 years were assessed using the bilateral stance test, limits of stability test, and the Functional Reach Test in the same manner as described in the assessment procedures, including the amount of practice and rest each individual was given. The one exception was that all testing in the pilot study was conducted with subjects' shoes off. The NBM[®] procedure manual was followed, and

both researchers were present during the assessment of the subjects.³⁸ To establish intrarater reliability, the same procedure was followed a second time, approximately one to two days later. Two subjects were released from the pilot study due to lack of effort during the second assessment, giving a remaining total eight subjects. The SPSS Version 10.0 (SPSS, Inc., Chicago, IL) was used to calculate intrarater reliability for all tests.

Intrarater Reliability

An intraclass correlation coefficient (ICC) was calculated from a repeated measures of analysis of variance (ANOVA) in order to assess test-retest reliability for each rater using both the NBM[®] and FRT, testing the subject on different days. One researcher tested subjects on the NBM[®], testing bilateral stance COG sway and limits of stability, while another researcher tested the same subjects on the FRT. Intrarater reliability results for bilateral stance test are reported in Table 1, while the intrarater reliability results for the limits of stability test and FRT are reported in Table 2 and Table 3 respectively.

Table 1. Bilateral Stance Test Intrarater Reliability Using ICC and r-value.

| Variable | Rater 1 ICC Value | Rater 1 r-value |
|-----------------------------|-------------------|-----------------|
| Eyes Open COG Sway Velocity | .8097 | .7251 |

Table 2. Limits of Stability Test Intrarater Reliability Using ICC and r-value.

| Variable | Rater 1 ICC Value | Rater 1 r-value |
|-------------------------------|-------------------|-----------------|
| Reaction Time Composite | .5042 | .3452 |
| Movement Velocity Composite | .9057 | .8321 |
| Maximum Excursion Composite | .7538 | .6359 |
| Directional Control Composite | .8299 | .7146 |

Table 3. Functional Reach Test Intrarater Reliability Using ICC and r-value.

| Variable | Rater 2 ICC Value | Rater 2 r-value |
|----------------------------|-------------------|-----------------|
| Functional Reach Test Mean | .9744 | .9501 |

ICC and r-value Interpretation

When calculating the intraclass correlation coefficient, there are no real standard values set for acceptable reliability. Values range between 0.00 and 1.00, with those numbers falling closer to 1.00 determining stronger reliability scores. As a general guideline, values above .75 are indicative of good reliability, while those below .75 represent poor to moderate reliability.⁴¹ It is generally considered that reliability should exceed .90 to ensure reasonable validity for clinical measurements. Table 4 represents an ICC value interpretation for intrarater reliability.

Table 4. ICC Value Interpretation.

| ICC Value | Interpretation |
|-----------|------------------|
| .90-1.00 | Very high |
| .75-.90 | Good |
| <.75 | Poor to Moderate |

The correlation coefficient r allows researchers to state mathematically the relationship that exists between two variables. The r -value may range from +1.00 through 0.00 to -1.00. An r -value of +1.00 indicates a perfect positive relationship, 0.00 indicates no relationship, and -1.00 indicates a perfect negative relationship.³⁹ Table 5 represents common interpretation of the correlation coefficient r . For further interpretation, both the ICC value and r -value were used in pilot study analysis. Results show ICC values ranging from good to very high with the exception of poor reaction time

results. Interpretation of r-values show results ranging from moderate to very high with the exception of poor reaction time.

Table 5. Correlation Coefficient r-value Interpretation.

| r value | Interpretation |
|----------|----------------|
| .90-1.00 | Very High |
| .70-.89 | High |
| .50-.69 | Moderate |
| .26-.49 | Low |
| 0.00-.25 | Little, If Any |

Data Analysis

The data gathered for all subjects on the limits of stability test, bilateral stance test, and Functional Reach Test were entered into the SPSS Version 10.0 software system. With this program, descriptive statistics including mean and standard deviation were calculated. Calculations were also done to determine values for the paired *t* test and Wilcoxon test. Comparisons between results were run using the Pearson correlation and Spearman correlation for further analysis.

Reporting of Results

Upon completion of this study, a copy of the results of this independent study was given to the University of North Dakota Department of Physical Therapy. This study was completed to fulfill the requirements of the University of North Dakota School of Medicine and Health Sciences Physical Therapy Program.

CHAPTER III

RESULTS

The results consisted of the limits of stability test scores and bilateral stance test scores from the NBM[®], as well as the Functional Reach Test scores. The data obtained from these assessments were analyzed using descriptive statistics to determine if any of the variables displayed significant results when comparing the shoes on condition to the barefoot condition. Comparisons were also made between test results and health and shoe questionnaire data collected prior to testing.

Subject Profile

Thirty female subjects, 20 to 26 years of age (mean age = 22.3 years), participated in this study. No subjects were excluded and all data was used. All subjects participated in a random one time testing session on the NBM[®] and FRT, both with elevated-soled shoes on and barefoot.

Descriptive Statistics

Descriptive statistics including mean and standard deviation were calculated from the data gathered during the one time testing session. For a listing of values from all tests, see Table 6. Only the components of testing found to be reliable during the initial pilot study were included in the data analysis as described in Chapter II.

Analytical Statistics

Analytical statistics were used to determine if a significant difference in static and dynamic balance existed between tests when comparing shoes on and barefoot

Table 6. NBM[®] Tests and FRT Descriptives

| Variable | N | Mean | SD |
|------------------------------------|----|--------|-------|
| Limits of Stability test: | | | |
| Reaction Time (seconds) | | | |
| Reaction Time-right (1) | 30 | .54 | .13 |
| Reaction Time-right (2) | 30 | .58 | .18 |
| Reaction Time-back (1) | 30 | .57 | .24 |
| Reaction Time-back (2) | 30 | .55 | .20 |
| Movement Velocity (degrees/sec) | | | |
| Movement Velocity-forward (1) | 30 | 8.49 | 2.17 |
| Movement Velocity-forward (2) | 30 | 8.18 | 2.49 |
| Movement Velocity-right (1) | 30 | 9.09 | 2.86 |
| Movement Velocity-right (2) | 30 | 8.29 | 2.87 |
| Movement Velocity-back (1) | 30 | 3.19 | 1.15 |
| Movement Velocity-back (2) | 30 | 3.87 | 1.32 |
| Movement Velocity-left (1) | 30 | 10.55 | 3.36 |
| Movement Velocity-left (2) | 30 | 9.78 | 3.07 |
| Endpoint Excursion (%) | | | |
| Endpoint Excursion-right (1) | 30 | 81.43 | 12.16 |
| Endpoint Excursion-right (2) | 30 | 75.70 | 13.30 |
| Endpoint Excursion-back (1) | 30 | 43.90 | 10.55 |
| Endpoint Excursion-back (2) | 30 | 47.70 | 15.88 |
| Maximal Excursion (%) | | | |
| Maximal Excursion-forward (1) | 30 | 112.30 | 9.28 |
| Maximal Excursion-forward (2) | 30 | 101.03 | 7.50 |
| Maximal Excursion-right (1) | 30 | 93.60 | 8.70 |
| Maximal Excursion-right (2) | 30 | 88.07 | 11.85 |
| Maximal Excursion-back (1) | 30 | 54.13 | 9.19 |
| Maximal Excursion-back (2) | 30 | 62.97 | 13.86 |
| Maximal Excursion-left (1) | 30 | 100.47 | 4.78 |
| Maximal Excursion-left (2) | 30 | 97.87 | 6.25 |
| Directional Control (%) | | | |
| Directional Control-forward (1) | 30 | 90.63 | 4.69 |
| Directional Control-forward (2) | 30 | 89.13 | 4.64 |
| Directional Control-back (1) | 30 | 49.10 | 27.52 |
| Directional Control-back (2) | 30 | 54.00 | 22.11 |
| Bilateral Stance Test: (%) | | | |
| Firm Surface-eyes open (1) | 30 | .27 | .15 |
| Firm Surface-eyes open (2) | 30 | .20 | .11 |
| Functional Reach Test: (cm) | | | |
| Functional Reach Test (1) | 30 | 42.56 | 5.04 |
| Functional Reach Test (2) | 30 | 38.43 | 5.56 |

Key: (1) – shoes off

(2) – shoes on

conditions. The nonparametric Wilcoxon test and parametric paired samples *t* test were both used in the data assessment. Results obtained from these two tests are listed in Table 7. An alpha level of .05 was chosen to determine significance.

The FRT scores and NBM[®] variables for the LOS and bilateral stance tests which were determined to be reliable during the initial pilot study were included in the data analysis. As Table 7 demonstrates, the following variables showed a significant change ($p < .05$) between testing with shoes on and barefoot: movement velocity-back, maximal excursion-forward, maximal excursion-right, maximal excursion-back, maximal excursion-left, bilateral stance on firm surface-eyes open, and the FRT. For the LOS test, movement velocity back was 0.68 degrees/second greater with shoes on compared to barefoot. This means that subjects moved to the back target during LOS testing slower with their shoes on than when barefoot. Also for the LOS test, maximal excursion forward was 11.27% greater barefooted compared to with shoes on, maximal excursion right was 5.53% greater barefooted compared to with shoes on, maximal excursion back was 8.84% greater with shoes on compared to barefooted, and maximal excursion left was 2.6% greater barefooted compared to with shoes on. Maximal excursion is defined as the furthest distance traveled by the subject's center of gravity (COG) during a trial of the LOS test. Therefore, subjects' were able to move farther forward, to the right, and to the left when barefoot compared to with shoes on and farther back with their shoes on compared to when barefoot.

For the bilateral stance test on the NBM[®], subjects average COG position was 7% greater when barefoot compared to with shoes on. This means that subjects' tended to sway to a greater percentage of their theoretical LOS while barefoot compared to while

Table 7. Wilcoxon and Paired *t* test Descriptives.

| Variable | Wilcoxon | | Paired <i>t</i> test | | |
|---|----------|----------|----------------------|----------|----------|
| | <i>z</i> | <i>p</i> | <i>df</i> | <i>t</i> | <i>p</i> |
| Limits of Stability: | | | | | |
| Pair 1 Reaction Time-right (1) – (2) | -1.46 | .14 | 29 | -1.51 | .14 |
| Pair 2 Reaction Time-back (1) – (2) | -.19 | .85 | 29 | .36 | .73 |
| Pair 3 Movement Velocity-forward (1) – (2) | -.30 | .77 | 29 | .63 | .53 |
| Pair 4 Movement Velocity-right (1) – (2) | -1.49 | .14 | 29 | 1.45 | .16 |
| Pair 5 Movement Velocity-back (1) – (2) | -2.42 | .02* | 29 | -2.73 | .01* |
| Pair 6 Movement Velocity-left (1) – (2) | -1.75 | .08 | 29 | 1.34 | .19 |
| Pair 7 Endpoint Excursion-right (1) – (2) | -1.89 | .06 | 29 | 2.03 | .05 |
| Pair 8 Endpoint Excursion-back (1) – (2) | -1.49 | .14 | 29 | -1.61 | .12 |
| Pair 9 Maximal Excursion-forward (1) – (2) | -4.39 | .00* | 29 | 5.71 | .00* |
| Pair 10 Maximal Excursion-right (1) – (2) | -3.09 | .00* | 29 | 3.58 | .00* |
| Pair 11 Maximal Excursion-back (1) – (2) | -3.91 | .00* | 29 | -4.52 | .00* |
| Pair 12 Maximal Excursion-left (1) – (2) | -2.26 | .02* | 29 | 2.57 | .02 |
| Pair 13 Directional Control-forward (1) – (2) | -1.33 | .19 | 29 | 1.65 | .11 |
| Pair 14 Directional Control-back (1) – (2) | -.94 | .35 | 29 | -1.07 | .30 |
| Bilateral Stance Test: | | | | | |
| Pair 15 Firm Surface-eyes open (1) – (2) | -3.01 | .00* | 29 | 3.46 | .00* |
| Functional Reach Test: | | | | | |
| Pair 16 Functional Reach Test (1) – (2) | -4.33 | .00* | 29 | -6.95 | .00* |

Key: (1) – shoes off

(2) – shoes on

* Significant difference between test conditions at $\alpha \leq .05$

wearing their shoes. Finally, for the FRT subjects' reached an average of 4.13 cm farther when barefoot compared to with shoes on. This means that subjects were able to reach farther, controlling the movement of their COG over a fixed base of support, when barefoot compared to while wearing their shoes.

Upon determination of the significant variables/scores for all tests, the variables in the shoes on condition were correlated to information obtained from the health and shoe questionnaires. Specifically, the frequency of shoe wear per week, heel height, heel area, and whether or not subjects felt safe while wearing their elevated shoes were chosen for comparison. Pearson and Spearman correlations were utilized to determine if any

significant relationships existed. See Tables 8 and 9, respectively for specific data regarding these correlations. An alpha level of .05 was used to determine significance.

A significant relationship was found between maximal excursion forward and subjective stability in shoes ($p = .046$, $r = -.366$) and between FRT scores and frequency of shoe wear per week ($p = .047$, $r = .366$) using the Pearson correlation. This means that about 14 % (i.e. $r^2 = -.366^2$) of the time a woman's maximal excursion forward score on the LOS test can be predicted by whether or not she feels stable in her elevated-soled shoes. A woman's FRT score can also be predicted by the number of times she wears her shoes per week the same percentage of the time. The Spearman correlation also showed a significant relationship ($p < .05$) between FRT scores and frequency of shoe wear per week ($p = .029$, $r_s = .399$), which reinforces the findings by the Pearson correlation. In addition, using the Spearman test, a significant correlation was found between the bilateral stance test and frequency of shoe wear per week ($p = .040$, $r_s = -.377$). This means that about 14% of the time a woman's bilateral stance test score can be predicted by the number of times she wears her elevated-soled shoes per week.

Based on the apparently close functional relationship of the NBM[®] maximal excursion-forward test and the Functional Reach Test, a correlation was run between the two to assess any significant relationships. A Pearson correlation and a Spearman correlation were both run. The findings showed no significant correlation between the two tests ($N = 30$, Pearson: $p = .548$, $r = .114$; Spearman's: $p = .914$, $r_s = .021$). Figure 5 represents a scatterplot diagram showing how the testing scores varied in relation to each other.

Table 8. Relationship of Shoe Conditions to Performance on LOS Test, Bilateral Stance Test and FRT using Pearson's Correlation Coefficient

| Variable | | Movement Velocity back | Maximal Excursion -forward | Maximal Excursion -right | Maximal Excursion -back | Maximal Excursion -left | Functional Reach Test | Bilateral Stance Test |
|-------------------------------------|---|------------------------------|----------------------------------|--------------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|
| Shoe Frequency / wk | r | -.186 | -.156 | .115 | .016 | .020 | .366 | -2.90 |
| | p | .326 | .411 | .546 | .932 | .917 | .047 * | .121 |
| Heel Height | r | -.322 | -.108 | -.165 | -.095 | .133 | .218 | -.059 |
| | p | .083 | -.570 | -.385 | .618 | .484 | .248 | .757 |
| Heel Area | r | -.196 | -.200 | -.132 | .112 | -.094 | .129 | -.075 |
| | p | .299 | .289 | .485 | .557 | .620 | .496 | .695 |
| Subjective Stability in Shoes | r | -.048 | -.366 | -.143 | -.012 | -.251 | -.197 | .011 |
| | p | .800 | .046 * | .451 | .948 | .180 | .298 | .952 |

* Significant correlation at $\alpha \leq .05$

Table 9. Relationship of Shoe Conditions to Performance on LOS Test, Bilateral Test, FRT, Spearman's Correlation Coefficient.

| Variable | | Movement Velocity- back | Maximal Excursion -forward | Maximal Excursion -right | Maximal Excursion -back | Maximal Excursion -left | Functional Reach Test | Bilateral Stance Test |
|-------------------------------------|----------------|-------------------------------|----------------------------------|--------------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|
| Shoe Frequency /wk | r _s | -.165 | -.179 | .122 | .022 | -.032 | .399 | -.377 |
| | p | .384 | .343 | .522 | .908 | .865 | .029 * | .040 * |
| Heel Height | r _s | -.356 | -.149 | .167 | .122 | .067 | .137 | .074 |
| | p | .054 | .431 | .377 | .520 | .727 | .471 | .698 |
| Heel Area | r _s | -.186 | -.219 | -.117 | .183 | -.141 | .122 | .016 |
| | p | .326 | .245 | .537 | .334 | .457 | .521 | .931 |
| Subjective Stability in Shoes | r _s | -.054 | -.336 | -.147 | .000 | -2.17 | -2.16 | .081 |
| | p | .777 | .069 | .438 | 1.000 | .250 | .251 | .670 |

* Significant correlation at $\alpha \leq .05$

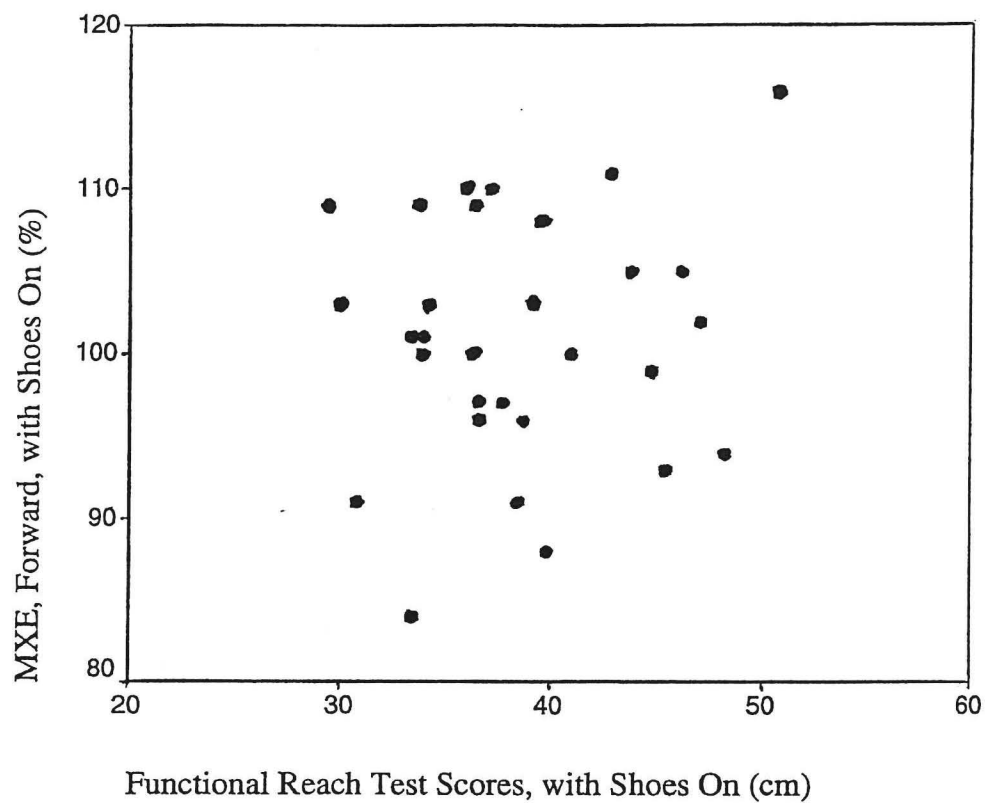


Figure 5. Scatterplot of Functional Reach Test scores and maximal excursion forward on NBM[®]

CHAPTER IV

DISCUSSION

The results of this study show that elevated-soled shoes have a significant affect on measurements obtained with the FRT and LOS and bilateral stance tests on the NBM[®] in younger women. It was determined that in the FRT and in 5 of 14 components of the LOS test on the NBM[®], subjects performed significantly ($p < .05$) better while barefoot than while wearing their own elevated soled shoes. These results support the initial hypothesis that there will be a significant decrease in dynamic balance when comparing the barefoot condition to the elevated-soled shoe condition. However, for the bilateral stance test on the NBM[®], results showed that subjects performed significantly ($p < .05$) better in static balance while wearing their own elevated-soled shoes compared to when barefoot. These results are in disagreement with the hypothesis that there will be a significant decrease in static balance when comparing the barefoot condition to the elevated-soled shoe condition.

The findings regarding dynamic balance complement previous research evidence on the effects of high-heel shoes, walking shoes, and a barefoot condition on kinematic and kinetic movement characteristics.^{4,6-8} In addition, the results are consistent with findings in a similar study done by Lord and Bashford²⁵ that examined the effects of high-heeled shoes on static and dynamic balance as measured by a “swaymeter.” In their study, women were found to perform significantly ($p < .05$) better in maximal balance

range in the anterior-posterior direction and in coordinated stability tests while in flat shoes or barefoot compared to while wearing high-heeled shoes. These two tests are comparable to the FRT and LOS test respectively.

Results regarding the differences in FRT scores between shoes on and barefoot conditions were also consistent with those determined by Arnadottir and Mercer²⁶ who found that subjects performed better on the FRT when barefooted or wearing walking shoes compared with when they wore dress shoes (i.e., high-heeled shoes). They reported an average 15% decline in FRT scores when analyzing the change from the barefoot condition to the dress shoe condition in their study that is relatively comparable to the average 10% decline in FRT scores (Table 1) from barefoot to elevated-soled shoe conditions observed in this study.

However, the findings of increased postural sway with the bilateral stance test while barefooted compared to while wearing elevated-soled shoes are not in agreement with previous literature examining the effects of high-heeled shoes on static balance. Lord and Bashford²⁵ found that women had significantly ($p < .05$) less postural sway when barefoot compared to wearing high-heeled shoes. However, this discrepancy in findings can perhaps be attributed to differences in experimental design. For example, with regard to the instrumentation used, Lord and Bashford²⁵ utilized a “swaymeter” to measure postural sway, whereas the NBM[®] bilateral stance test was used in this study. The “swaymeter” has been proven to have test-retest reliability of 0.81 (95% CI = 0.66-0.90) for postural sway in previous studies,^{36,37} while according to the NBM[®] operator’s manual, the bilateral stance test has a relatively poor reliability of 0.52 ($r < .60$).³⁸ Also, in their study subjects wore standardized spiked high-heeled shoes with a heel height of 6

cm, whereas in this study subjects wore their own elevated-soled shoes (heel heights varied from 4.4 cm to 8.7 cm) with a much wider based heel. It is possible that the differences in shoe design may have contributed to the differences in postural sway observed between the two studies.

In addition to the significant differences found between the shoes on and barefoot conditions determined for all three tests (bilateral stance test, LOS test, and FRT), a significant correlation (Pearson: $p = .047$; Spearman: $p = .029$) was also found between subjects' frequency of shoe wear per week and their FRT scores. However, these results must be examined with caution because according to statistical interpretation this means that a subjects FRT score can be predicted by the number of times she wears those same pair of shoes per week approximately 14% of the time. Therefore, although the correlation was found to be significant, the predictive value of frequency of shoe wear per week to FRT scores is virtually negligible.

A significant correlation (Pearson: $p = .040$) was also found between the maximal excursion forward component of the LOS test and whether or not subjects' felt stable in their shoes. However, one must again be cautioned when interpreting these results because this means that a subject's maximal excursion forward on the LOS test can be predicted by whether or not a subject feels stable in their shoes about 14% of the time. No significant correlations (Table 3 and 4) were found between frequency of shoe wear per week and LOS or bilateral stance test scores although one would have postulated that a woman who wears her shoes more frequently would have better scores on these tests. Also, no significant correlations (Table 3 and 4) were determined between heel height, heel area, and whether or not a subject felt stable in her elevated-soled shoes with regard

to LOS test scores, bilateral stance test scores, or FRT test scores. This could be due to the high degree of variation in elevated-soled shoe styles observed, as well as the high degree of subjectivity associated with a woman's feelings of relative stability in her shoes. Based on the functional similarity between the maximal excursion forward position in the LOS test and the FRT a final correlation was attempted to be made between the two. However, it was determined that no significant relationship existed (Figure 2). The lack of correlation could possibly be attributed to the fact that the LOS test is a computer-based test while the FRT is manual test. Also, whereas subjects could assume any number of body positions to achieve their maximal excursion forward position in the LOS test, body positioning was somewhat controlled in the FRT per testing protocol.

Limitations

Although this study is in agreement with much of the findings on the effects of high-heeled shoes on postural stability and balance, particularly in older people, it is acknowledged that it has certain limitations. In addition to some of the limitations previously mentioned, six more major limitations will be discussed here.

First, it must be noted that direct comparisons to similar studies must be cautioned secondary to much of the previous research utilizing spiked style high-heeled shoes, whereas elevated-soled shoes with much broader based heels were used in this study. In fact, Carol Frey, M.D., an interim clinical professor of orthopedic surgery at UCLA, recently said in reference to platform-style shoes that "this design distributes the person's weight more evenly across the shoe, because there is little or no decline."^{14(p21)}

Therefore, it is possible that this style of shoe may actually offer greater stability to the wearer than the “traditional” high-heeled shoe.

Secondly, because subjects wore their own elevated-soled shoes and the only inclusion requirement was that those shoes had a minimum heel height of 4 cm, a relatively high degree of variation was seen with the different shoe styles of subjects. For instance, heel heights ranged from 4.4 cm to 8.7 cm with an average heel height of 6.18 cm, and heel areas ranged from 15.75 cm² to 64.00 cm² with an average heel area of 48.64 cm². Shoe styles also varied from those with soles with a distinct separation between the forefoot and the heel with both small and large wedge-styled heels to continuous-style soles (i.e., platform-style) with no distinct separation between the forefoot and the heel. See Appendix E for examples of shoes used in this study. Also, some shoes were closed-toed while others were open-toed, some had heel counters whereas others did not, some were a laced-style while others were slip-ons, and there was no method for ascertaining sole hardness. Therefore, although a minimum heel height was established and subjects were allowed to wear their own shoes to improve the generalizability of results, the degree of variation in heel heights, heel areas, and style of shoes may have influenced the results.

Thirdly, the instrumentation utilized, namely the NBM[®], may have limited the results of this study. This is because it has been purported that the LOS test on the NBM[®] has a relatively high learning curve for the user.^{29,40} Therefore, subject errors could have possibly been attributed to a lack of practice and familiarization with the NBM[®], as opposed to actual balance deficits, especially due to the fact that all subjects only participated in a one time testing session. Typically, a subject would be allowed to

have adequate practice on the NBM[®] and then be tested twice with data from the second testing session being utilized for analysis, however, based on research time constraints this was not possible.

Many questions also still remain with regard to the NBM[®] reliability of LOS test results. For example, from the pilot study conducted in this study only 14 of a possible 20 variables (excluding 5 composite variables) were determined to be reliable for the LOS test. This could be due to the small number of subjects ($n = 8$) who participated in the pilot study. It is possible that if a larger study sample were used the reliability of results could be improved. However, the NBM[®] operator's manual reports that for the LOS test, the only the composite variable that demonstrates high reliability ($r = 0.80$) is movement velocity.³⁸ The other composite variables (reaction time: [$r = 0.74$], maximal excursion: [$r = 0.76$], end-point excursion: [$r = 0.73$], and directional control: [$r = 0.68$]) all demonstrate only moderate reliability. In addition, calibration errors may have limited the results of the pilot study as well as the actual study because calibration of the NBM[®] used in this study was last done two years prior to testing.

Fifthly, results may have been limited by the variation in the time of day in which subjects were tested, as testing was conducted in the morning, afternoon, and evening. Diurnal changes may have contributed to enhanced or decreased balance in certain subjects. Again, due to research time constraints testing all subjects at the same time of day was not possible.

Finally, the fact that all subjects in the study population consisted of students enrolled in the professional physical therapy program at the University of North Dakota may have limited study results secondary subjects' advanced knowledge of balance and

different balance strategies. All subjects also reported being physically active with majority of subjects participating in some form of exercise at least 3-4 times per week. It is possible to infer that due to their active life-style these subjects may have better balance than a more well distributed population of people in a similar age range.

Recommendations

Based on the significant findings of decreases in limits of stability and functional reach and increases in static steadiness when comparing barefoot to elevated-soled shoes conditions, it is evident that there is still a need for further research regarding these styles of shoes. Research should be concentrated on identifying specific shoe characteristics that provide the greatest benefits for given physical and environmental conditions. Some recommendations for future research will be discussed here.

First, although this study used subject's own shoes to improve the generalizability of results, perhaps introducing standard low and elevated-soled shoe conditions into the experimental design could help control for common differences in shoe characteristics and styles. In addition, with regard to the measurement of shoe dimensions, future studies should take into account and investigate the effects of adjusted heel heights compared to heel heights alone. Although the forefoot height of soles were recorded in this study, only the actual heel heights were included for data analysis. Future studies should investigate the affect that adjusted heel heights (i.e., heel height – forefoot height) have on static and dynamic balance. This is important because in all likelihood adjusted heel heights would be much less than the heel height alone for these styles of shoes.

Secondly, in addition to tests for static and dynamic balance, the NBM[®] could be used to assess functional balance tasks through the use of functional balance tests such as

the sit-to-stand test, step and quick turn test, and the step up/over test. These tests would allow researchers to examine the effects of elevated-soled shoes on balance in functional situations. Also, all testing done on the NBM[®] should consist of a pilot study to ensure reliability of results. Adequate practice time should be allotted to subjects and at least two testing sessions should be administered to help control for the high learning curve associated with the instrument.

Thirdly, futures studies could look at a subjects' lateral reach, in addition to their functional reach, in order to gain a better understanding of how elevated-soled shoes affect dynamic balance in the lateral direction as well as the anterior-posterior direction. This is because so many functional activities that are carried out on a daily basis involve reaching to either side of a person's body. In addition to the FRT, lateral reach results could provide the means for comparison to LOS test scores in all directions.

Fourthly, in order to further establish and control for a subjects baseline balance the use of standardized balance tests such as the Tinetti⁴² balance assessment tool and Berg⁴³ Balance test could be implemented as part of the experimental design. Comparisons could then be made to results of static and dynamic balance ascertained from tests on the NBM[®] and the FRT.

Finally, further research should be conducted with a pathologic population of those with a history of falls secondary to elevated-soled shoes. This could help provide some insight into other predisposing factors that contribute to falls with these styles of shoes.

Conclusion

This study indicates that the type of footwear a younger woman is wearing can have an effect on her scores on the FRT, as well as the LOS and bilateral stance tests as assessed on the NBM[®]. In tests of dynamic balance, performance in the FRT and in 5 of 14 components of the LOS test was better when barefoot compared to the elevated-soled shoe condition. Moreover, in the lone test of static balance, performance in the bilateral stance test was better when wearing elevated-soled shoes than for the barefoot condition.

These findings appear to present a somewhat conflicting picture regarding the relative affect that elevated-soled shoes have on static and dynamic balance. However, since this style of shoe was found to have some detrimental effects on the dynamic balance of the study population, the relative safety of these styles of shoes must be brought into question. It is paramount, then, that clinicians carefully document and make proper shoe recommendations to clients regarding their footwear. The current study findings could also assist in establishing public health initiatives, such as the shoe warning labels now being implemented in Japan, aimed at influencing younger people to use safe shoes. Whereas much of the previous research has documented evidence that high-heeled shoes constitute a needless hazard for older women, this study illustrates that much of the same hazards exist for younger women wearing an elevated-soled style of shoe.

APPENDIX A

☒ EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER(S)) OF HHS REGULATIONS
☐ EXEMPT REVIEW REQUESTED UNDER ITEM _____ (NUMBER(S)) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

Please include ALL information and check ALL blanks that apply.

PRINCIPAL INVESTIGATOR: Rhett Randall & Kip Ouchi TELEPHONE: 746-0722 DATE: 04/02/00
Rhett 777-9599
Kip
UND Physical Therapy Department P.O. Box 9037
Grand Forks, ND 58202-9037
ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: University of North Dakota DEPARTMENT: Physical Therapy PROPOSED PROJECT DATES: 04/03/00- 07/01/00
(Month/Day/Year)
SCHOOL/COLLEGE: University of North Dakota DEPARTMENT: Physical Therapy PROJECT DATES: 04/03/00- 07/01/00
(Month/Day/Year)
PROJECT TITLE: The Effects of Elevated Shoe Heights on Static and Dynamic Balance in Healthy Younger Women

FUNDING AGENCIES (Include copy of proposal): _____

TYPE OF PROJECT (Check ALL that apply):

NEW PROJECT ☒ CONTINUATION ☐ RENEWAL ☐ DISSERTATION OR THESIS RESEARCH ☒ STUDENT RESEARCH PROJECT
☐ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Meridee Danks

PROPOSED PROJECT: ☐ INVOLVES NEW DRUGS (IND) ☐ INVOLVES NON-APPROVED USE OF DRUG ☐ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATION, PLEASE INDICATE THE CLASSIFICATION(S):

☐ MINORS (<18 YEARS) ☐ PREGNANT WOMEN ☐ MENTALLY DISABLED ☐ FETUSES ☐ PERSONS WITH
☐ PRISONERS ☐ ABORTUSES ☒ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ☐

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): _____

Status: ☐ Submitted; Date _____ ☐ Approved; Date _____ ☐ Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

Balance is an essential component in carrying out all activities of daily living. The maintenance of balance is a complex process which involves the interplay between the central nervous system and musculoskeletal system. Many factors contribute to an individual's ability to safely maintain balance. Some of these are intrinsic factors such as neurological, vestibular, or orthopedic deficits, while others are extrinsic factors such as one's surrounding environment or a person's footwear. Footwear, and its effect on balance, particularly in the elderly population, has been a topic of interest to researchers who have looked at ways of improving fall risk management. In particular, much research has been conducted regarding varying heel heights and its effect on balance in the elderly. However, limited research has been done to look at the impact of elevated shoe heights on the balance of a young, normal population. It appears that a growing fashion trend among younger women is towards the wearing of

dress/casual shoes with higher overall sole heights during both everyday activities and social events. With increased shoe heights may come deficits in static and/or dynamic balance. The purpose of this study is to determine what effect elevated shoe heights have on the balance of young women as assessed by the NeuroCom Balance Master and the Functional Reach Test. This study will hopefully help provide some insight as to the relative safety of higher soled shoes which have become much more prevalent in recent years and to assist phys therapists in making proper shoe recommendations to clients, especially those that may be challenged by balance deficits or low back pain.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subject will be asked to complete.)

Subjects:

Subjects will consist of at least 20 healthy volunteers from the University of North Dakota student and/or faculty population. Recruitment will be carried out by the researchers and done by word of mouth. A questionnaire administered before participation will be used to obtain health and shoe information that may influence the subjects balance and subsequent participation in the study. Subjects will be selected on the basis of meeting the following inclusion criteria: 1) each subject will be within the range of 20-39 years of age, 2) each subject will have no current or past medical diagnosis or history affecting balance, 3) each subject will be taking no medications affecting the central nervous system (CNS) or medications known to affect balance/coordination, 4) each subject will have no symptoms of dizziness or lightheadedness, 5) each subject will have no symptoms suggestive of vestibular or neurologic disorders, 6) each subject will have no psychological disorders including depression, 7) each subject will have no history of two or more unexplained falls within the past 6 months, 8) each subject will have normal vision with or without glasses, 9) each subject will own a pair of dress/casual shoes with a heel height of at least 4 cm, and 10) each subject will have worn these elevated shoes at a frequency of at least once a week. No volunteers in this age group will be excluded from this study unless there is a safety or health concern. Informed consent for this study will be obtained via a signed consent form (attached) before any testing procedures are performed.

Instrumentation:

The NeuroCom® Balance Master system will be used in this study. It is a clinically acceptable and safe machine commonly used in physical therapy to assess balance. The NeuroCom® Balance Master system operates on two 9-inch by 60-inch forceplates that determine the amount of force being exerted by each foot. The total force information is transferred to the computer system where calculations are performed to determine the test subjects' center of gravity and postural sway. The computer screen is equipped with a cursor to provide visual feedback on the location of the subjects center of gravity. The computerized measurements and feedback systems are what make the system unique and beneficial to both the subject and researcher. The Functional Reach Test will also be used in this study. Intra-reliability for testing using the NeuroCom® Balance Master and Functional Reach Test will be established prior to the start of the study through an instrumentation class which each member of the research team is currently enrolled in. Validity of the NeuroCom® Balance Master has been established through its ability to generate computerized printouts of objective, quantifiable data. Validity of the Functional Reach Test has also been established

through numerous clinical studies. Published literature supports the scientific efficacy and clinical use of both the NeuroCom® Balance Master and Functional Reach Test and acknowledges both as reliable and valid tools for assessing balance.

Procedure:

All testing will be conducted in the research room at the UND Physical Therapy Department. Each subject will be assessed once in random order. The tests to be assessed will be drawn randomly without replacement one at a time from a hat. Each subject will then perform a warm-up of each test prior to performing the recorded test, in the order they were drawn. The warm-up will allow the subjects to familiarize themselves with the NeuroCom® Balance Master and Functional Reach Test. It will allow the subjects to assess how to control their center of gravity and postural sway. The high learning curve associated with the NeuroCom® Balance Master requires the subject to perform a trial assessment before any results are recorded. Standardized testing procedures as described in the NeuroCom® Balance Master manual will be followed by the researchers for the following tests:

- 1) Bilateral Stance with shoes on and off (an indicator of static balance skills)

This testing procedure requires the subject to stand as still as possible on both feet for 10 seconds with shoes on and shoes off.

- 2) Limits of Stability Test with shoes on and off (an indicator of dynamic balance skills)

This test requires the subject to shift their weight and lean in all directions including: forward, backward, sideways, and diagonally. During this test, the subject will be required to maintain their balance while keeping their feet planted on the force platform.

In addition, the Functional Reach Test will be conducted with shoes on and off (as an indicator of dynamic balance skills). This test is measured with the subject in a standing position. The subject reaches forward with his/her dominant hand along a ruler placed on the wall. The subject is instructed to reach as far forward as possible without taking a step or losing balance. Each subject will perform 2 practice trials and then 3 measured trials in order to minimize possible learning effects.

For all testing, appropriate dress/casual shoes will be defined as having a firm sole and a heel height of at least 4 cm (1.6 in.). The heel height will be established by measuring the vertical distance from the floor to the insole at the front of the heel. Other shoe characteristics such as the flare of the sole and firmness of the sole will be qualitatively judged and documented.

Testing procedures will take approximately 20-45 minutes with members of the research team present at all times to ensure the complete safety of all participants.

Data Analysis and Reporting:

Statistical analysis of the data will consist of descriptive and analytical statistics. A related samples t-test or the most appropriate method of statistical analysis will be used. The individual subjects' results will remain confidential, and the data will be identified in a manner that maintains subject confidentiality. All data, questionnaires, and consent forms will be kept in a confidential file at the Department of Physical Therapy (room 1518), University of North Dakota and will be kept for a three-year period, at the end of which the documents will be shredded.

3. BENEFITS: (Describe the benefits to the individual or society.)

This study has the potential for many benefits to both individual participants and society. Through assessment using the NeuroCom® Balance Master and the Functional Reach Test, each participant will learn about the relative safety of their own dress/casual shoes and also desired shoe characteristics to look for when purchasing future shoes. Participants will also become aware of their relative balance when not wearing any type of footwear. Data results will help provide physical therapists and other health professionals with evidence based research to assist in proper shoe recommendations for clients and/or aid in activity selection involving dynamic balance while wearing higher soled shoes. This could in turn help prevent or decrease the risk of injuries occurring secondary to loss of balance created by inappropriate footwear. Finally, results could be utilized by shoe manufacturers in developing safer shoes for the consumer.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, debriefing procedures, storage of data for the required three years, final disposition of data, etc.)

The risks associated with this study are minimal, but those that exist will be controlled. The physical risks include possible loss of balance during the assessment on the NeuroCom® Balance Master and during the Functional Reach Test. The risk of falling, however, will be minimized by having at least one member of the research team spotting subjects during all testing procedures. In addition, verbal instructions and demonstrations will be given to subjects prior to and during balance assessment.

Participants dignity, self-respect, and privacy will be protected by the research team by 1) testing all subjects in a private, controlled environment, 2) giving subjects complete instructions regarding their role in the research project, 3) scheduling individual testing sessions to promote privacy, 4) informing the subjects that all information pertaining to their history and performance will be disclosed only with a number and that no names will be used, and 5) informing the subjects that this is a voluntary exercise and they may withdraw at any time from the testing without fear of retribution or prejudice.

5. **CONSENT FORM:** Attach a copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept for the required 3 years, including plans for final disposition or destruction.

Informed consent will be obtained through the attached consent form. Each subject will be required to sign the form if they agree with the terms that are presented. Upon agreement, they will be included in the study.

All consent forms, questionnaires, and data reports will be kept in a locked confidential file located in the Physical Therapy office (room 1518) of the University of North Dakota School of Medicine and Health Sciences. Data and information obtained from the study will be kept for 3 years following the completion of the study. At the end of this three year period the documents containing this information will be disposed of with the use of a shredder. Please see attached consent form.

6. For **FULL IRB REVIEW** forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to the address below. An original and 19 copies are required for clinical medical projects. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical medical.

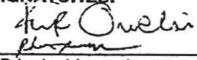
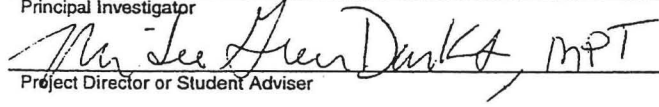
Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

| | |
|--|-----------------------|
|  Principal Investigator | <u>4/7/00</u> Date |
|  Project Director or Student Adviser | <u>4-7-00</u> Date |
| _____ Training or Center Grant Director | _____ Date |

(Revised 4/1998)

APPENDIX B

Consent Form

Title: The Effects of Elevated Shoe Heights on Static and Dynamic Balance in Healthy Younger Women

You are invited to participate in an independent study conducted by students of the UND physical therapy program (Kip Ouchi & Rhett Randall) in collaboration with faculty member Meridee Danks. Your participation in this study would be greatly appreciated and it should be noted that it is strictly voluntary.

The purpose of this study is to determine what effects elevated shoe heights have on the balance of young women as assessed by the NeuroCom® Balance Master and Functional Reach Test. The NeuroCom® Balance Master is a clinically acceptable machine commonly used to assess balance in physical therapy. Subjects for this study must be healthy individuals between the ages of 20-39. All volunteers in this age group must meet the following inclusion criteria: 1) No current or past medical diagnosis or injury affecting balance, 2) No medications affecting the central nervous system or known to affect balance/coordination, 3) No symptoms of dizziness or lightheadedness, 4) No symptoms suggestive of vestibular or neurologic disorders, 5) No psychological disorders including depression, 6) No history of two or more unexplained falls within the past 6 months, 7) Normal vision with or without glasses, 8) Must own a pair of dress/casual shoes with a heel height of at least 4 cm (1.6 in.), and 9) Must wear your elevated shoes at least once a week. You will be asked to fill out a brief health and shoe questionnaire prior to the start of the study in order to protect you from injury and help us interpret our results. We do ask that you bring shoes with a heel height of at least 4 cm and be prepared to be tested in these shoes as well as barefoot when participating in the study.

You will only be asked to participate in a one time testing session lasting 20-45 minutes. You will be asked to report to the research room on the second floor of the UND Physical Therapy Department at your scheduled testing time. This session will include assessment on the NeuroCom® Balance Master, tested with both dress/casual shoes on and barefoot, as well as a Functional Reach Test. Balance Master tests will include: 1) standing as still as possible on both feet for a fixed period of time, tested both with shoes on and barefoot, and 2) leaning forward, backward, sideways, and diagonally without moving your feet, tested both with shoes on and barefoot. The Functional Reach Test will include standing without moving your feet while reaching forward with your dominant hand along a measuring device placed on the wall.

Although the process of balance testing involves some risk of falling and injury, the researchers of this study feel the risk of injury is minimal. In order to reduce this risk of falling, an assistant will be provided to safeguard you from possible loss of balance during the assessment. If you should choose to participate in this study, you will benefit from exposure to the research process and the knowledge that you have been an active

participant in helping to improve the field of physical therapy. You may also benefit from learning a little more about the relative safety of your dress/casual shoes.

The results of this study will remain confidential and your data will be identified by a number known only to the investigators. These results will be kept in a locked confidential file in the UND Physical Therapy Department for three years following the completion of the study. After this period of time, the results will be destroyed. If you decide to participate, you are free to withdraw your participation at any time for any reason. You may stop the experiment at any time if you are experiencing pain, discomfort, fatigue, or any other symptoms that may be detrimental to your health. Your decision not to participate in this study will not affect your future relationship with the University of North Dakota or the Physical Therapy Department. If it is determined that you have health issues that put you at risk for injury or you do not meet the inclusion criteria, you may be excluded from the study. However, again, you will not be penalized in any way.

The investigators are available to answer any questions you might have concerning this study now or in the future. Questions may be answered by contacting Kip at (701) 746-0722 or Rhett at (701)777-9599. A copy of this consent form will be available to all participants in the study upon request. If you would like to contact Meridee she can be reached at (701) 777-3861.

In the unlikely event that this research project results in physical injury or medical treatment including first-aid, emergency treatment, or any follow-up care, the investigators along with the University of North Dakota are not responsible for any such injury or treatment. The payment for any such treatment must be provided by you and your third party payer, if applicable.

I have read all the above, all my questions have been answered, and I willingly agree to participate in this study explained to me by Kip Ouchi and Rhett Randall.

Participant's Signature

Date

Witness (not Investigator)

Date

APPENDIX C

Health Background Questionnaire

1. Are you currently taking any medications? (e.g. allergy medications, cold medications, etc.) Please list all over-the-counter and/or prescription medications in order for us to determine if these may affect your balance.

2. Do you have any current or past medical diagnoses or injuries occurring within the last year that could affect your balance? If so, please list them and their associated dates. (include fractures, orthopedic conditions, sprains, etc.)

3. Do you have any symptoms (e.g. dizziness, lightheadedness) associated with a vestibular disorder? If yes, please explain your symptoms.

4. Have you experienced any episodes of two or more unexplained falls within the past 6 months? If so, please list.

5. Do you have normal vision (either with or without glasses/contacts)?

6. What is your height and weight?

7. What is your date of birth? (month/day/year)

8. Please circle which is your dominant hand? Right Left

9. How many times a week do you exercise? (please circle)

0 days 1-2 days 3-4 days 5+ days/week

What type of physical activities are you involved in?

Shoe information

1. What is your shoe size?
2. How often do you wear your high-soled shoes? (i.e. days per week)
Please note that shoes must have a heel height of at least 1.6 inches.
3. Are your high-soled shoes seasonal?
4. Do you notice any changes in your activity level when wearing your high-soled shoes? If so, please explain.
5. Are your high-soled shoes comfortable to wear?
6. Do you feel your balance is impaired in any way while wearing your high-soled shoes? If so, please explain.
7. Do you wear orthotics of any type in your shoes? If so, for what condition?

APPENDIX D

Computer Results Example

University of North Dakota
School of Medicine & Health Sciences
501 N Columbia RD
Grand Forks, ND 58202-9037

Name: 277, 277

Diagnosis:

File: HBM401.QBM

ID: ATID00401

Operator: Randall, Rhett L

Test Date: 5/5/2000

DOB: 7/26/1978

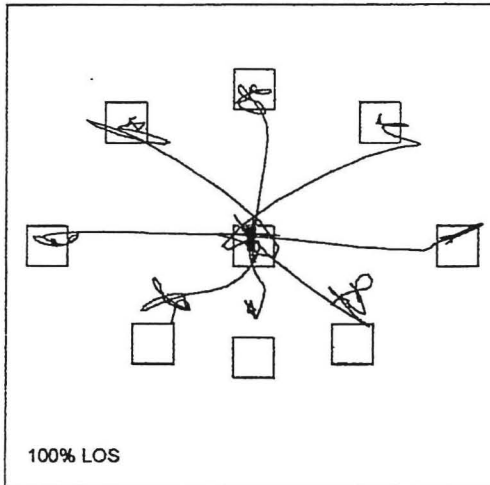
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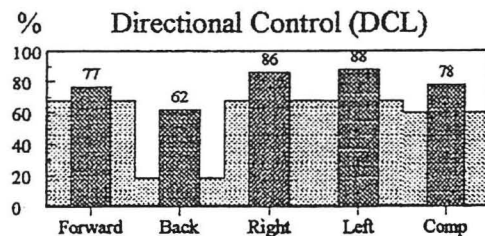
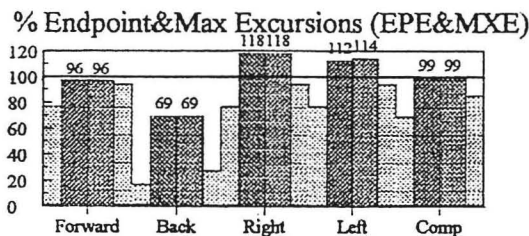
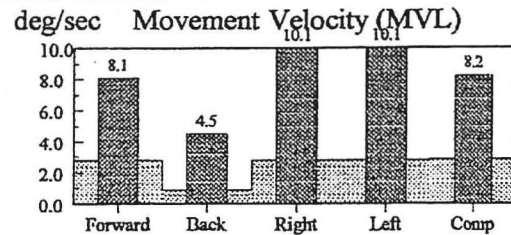
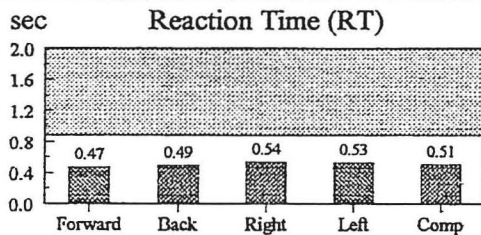
Height: 5'4"

Comments: elevated shoe height study

LIMITS OF STABILITY TEST



| Transition | RT (sec) | MVL (deg/sec) | EPE (%) | MXE (%) | DCL (%) |
|------------|-------------|------------------|------------|------------|------------|
| 1 (F) | 0.51 | 6.2 | 103 | 103 | 88 |
| 2 (RF) | 0.61 | 11.7 | 108 | 110 | 83 |
| 3 (R) | 0.46 | 6.2 | 112 | 112 | 92 |
| 4 (RB) | 0.41 | 10.0 | 99 | 99 | 57 |
| 5 (B) | 0.67 | 2.6 | 65 | 65 | 87 |
| 6 (LB) | 0.54 | 5.0 | 89 | 89 | 58 |
| 7 (L) | 0.42 | 10.9 | 102 | 107 | 93 |
| 8 (LF) | 0.49 | 11.8 | 117 | 117 | 89 |



Data Range Note: NeuroCom Data Range: 20-39

Post Test Comments:

shoes off

University of North Dakota
School of Medicine & Health Sciences
501 N Columbia RD
Grand Forks, ND 58202-9037

Name: 277, 277

Diagnosis:

File: HBM401.QBM

ID: ATID00401

Operator: Randall, Rhett L

Test Date: 5/5/2000

DOB: 7/26/1978

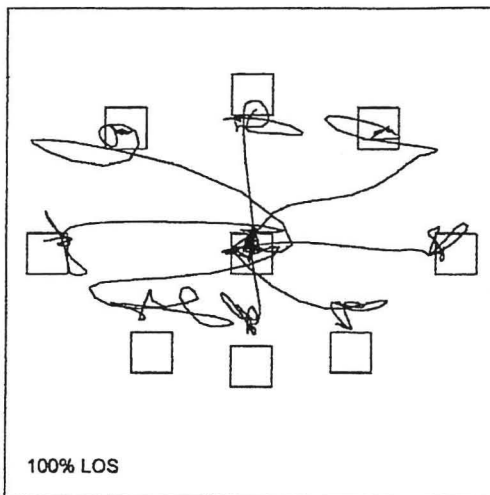
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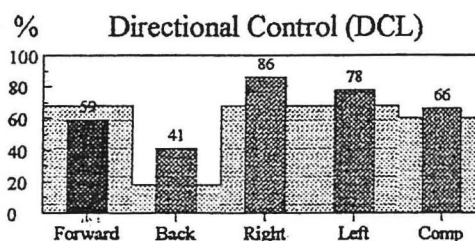
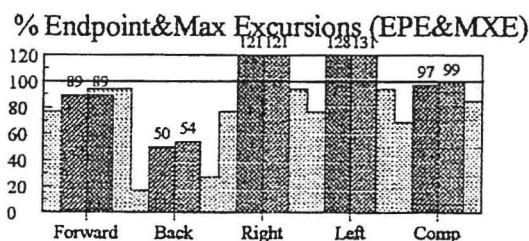
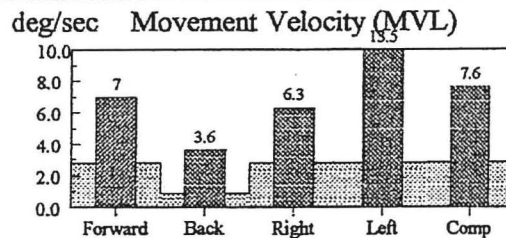
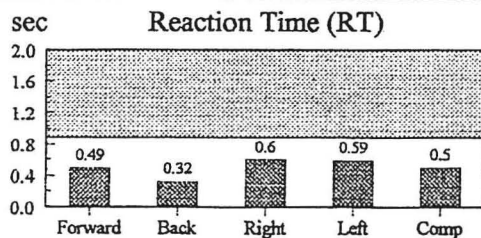
Height: 5'4"

Comments: elevated shoe height study

LIMITS OF STABILITY TEST



| Transition | RT (sec) | MVL (deg/sec) | EPE (%) | MXE (%) | DCL (%) |
|------------|-------------|------------------|------------|------------|------------|
| 1 (F) | 0.70 | 7.5 | 96 | 96 | 76 |
| 2 (RF) | 0.54 | 5.7 | 115 | 115 | 74 |
| 3 (R) | 0.50 | 4.3 | 106 | 106 | 86 |
| 4 (RB) | 0.51 | 6.5 | 93 | 93 | 61 |
| 5 (B) | 0.45 | 4.0 | 62 | 72 | 66 |
| 6 (LB) | 0.61 | 9.3 | 101 | 101 | 46 |
| 7 (L) | 0.42 | 10.6 | 93 | 101 | 84 |
| 8 (LF) | 0.47 | 14.6 | 133 | 133 | 67 |



Data Range Note: NeuroCom Data Range: 20-39

Post Test Comments:

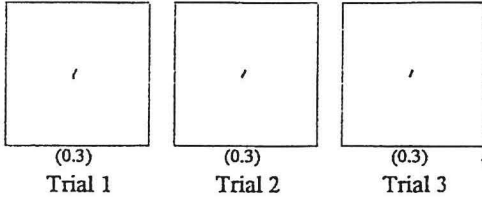
shoes on

University of North Dakota
School of Medicine & Health Sciences
501 N Columbia RD
Grand Forks, ND 58202-9037

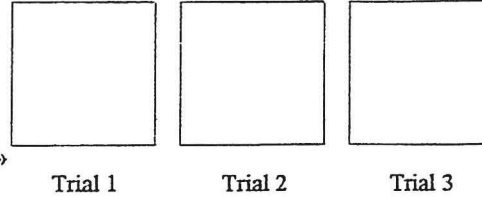
| | | |
|-----------------------|---|-------------------------------|
| Name: 277, 277 | Diagnosis: | File: HBM401.QBM |
| ID: ATID00401 | Operator: Randall, Rhett L | Test Date: 5/5/2000 |
| DOB: 7/26/1978 | Referral Source: | Test Time: 12:38:55 PM |
| Height: 5'4" | Comments: elevated shoe height study | |

MODIFIED CLINICAL TEST FOR SENSORY INTERACTION ON BALANCE (CTSIB)

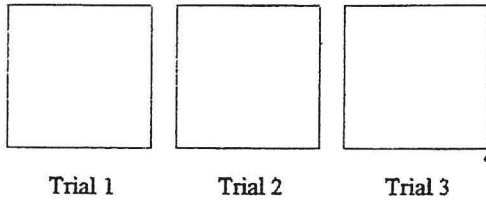
1. Firm--Eyes Open (FIRM-EO)



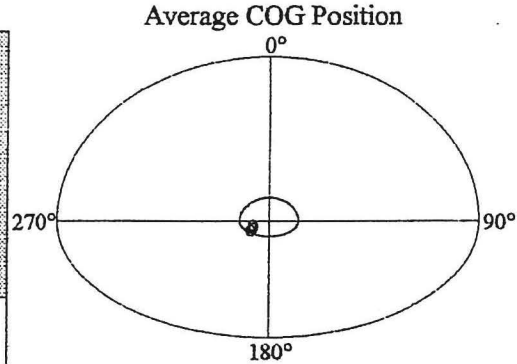
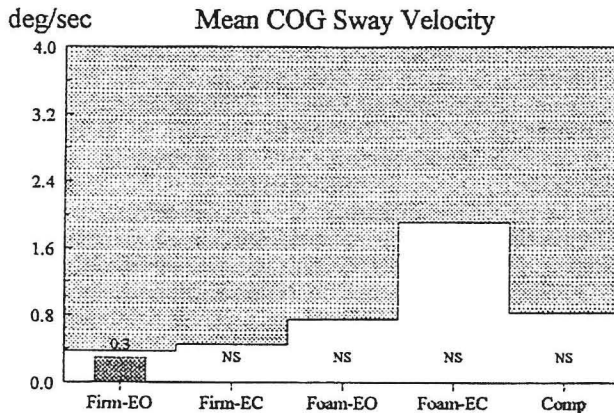
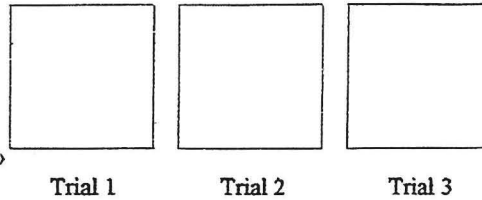
2. Firm--Eyes Closed (FIRM-EC)



3. Foam--Eyes Open (FOAM-EO)



4. Foam--Eyes Closed (FOAM-EC)



o = Firm-EO + = Firm-EC
* = Foam-EO x = Foam-EC

Average COG Position:
Left/Back, 10%LOS @244.7 degree

Data Range Note: NeuroCom Data Range: 20-39

Post Test Comments:

shoes off

University of North Dakota
School of Medicine & Health Sciences
501 N Columbia RD
Grand Forks, ND 58202-9037

Name: 277, 277

Diagnosis:

File: HBM401.QBM

ID: ATID00401

Operator: Randall, Rhett L

Test Date: 5/5/2000

DOB: 7/26/1978

Referral Source:

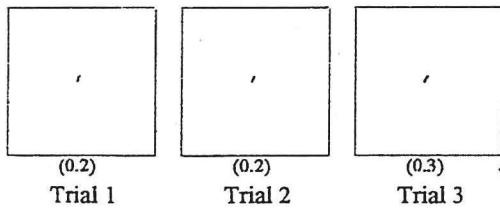
Test Time: 12:30:28 PM

Height: 5'4"

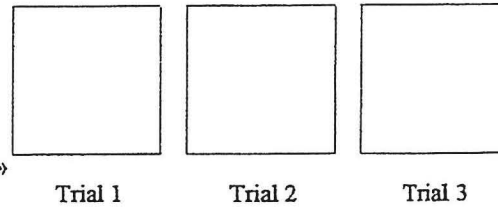
Comments: elevated shoe height study

MODIFIED CLINICAL TEST FOR SENSORY INTERACTION ON BALANCE (CTSIB)

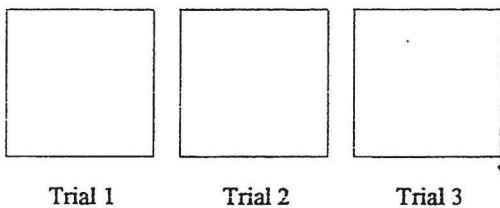
1. Firm--Eyes Open (FIRM-EO)



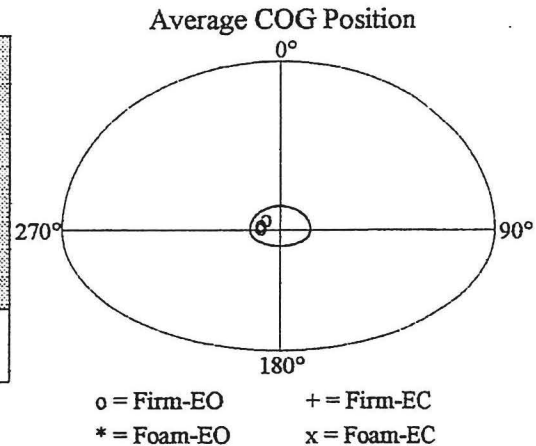
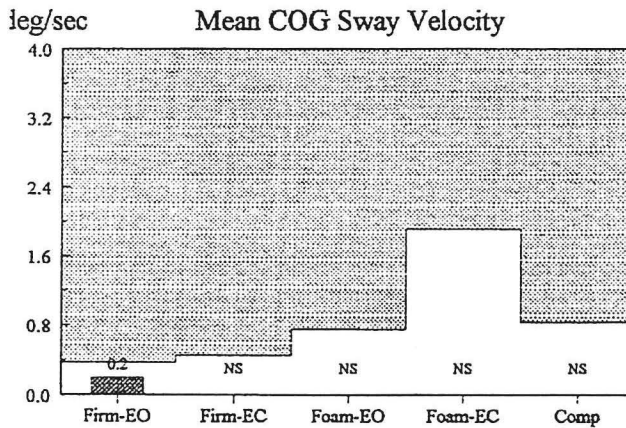
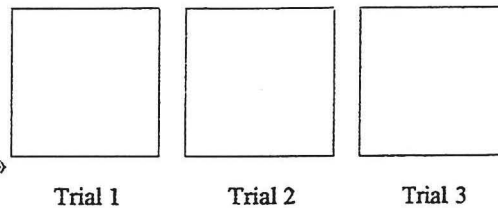
2. Firm--Eyes Closed (FIRM-EC)



3. Foam--Eyes Open (FOAM-EO)



4. Foam--Eyes Closed (FOAM-EC)



Average COG Position:

Left, 8%LOS @281.9 degree

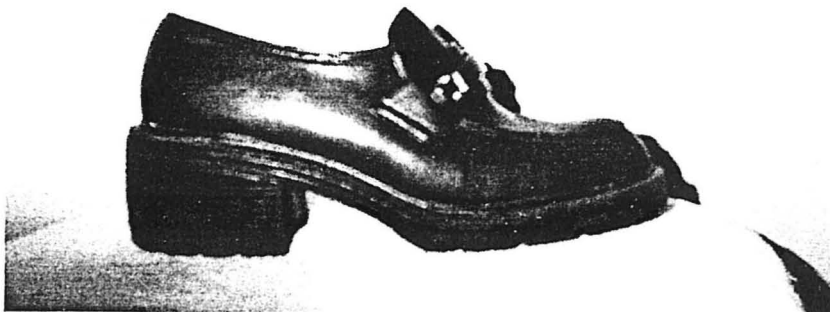
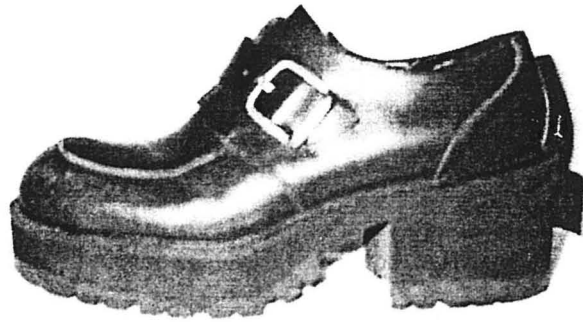
Data Range Note: NeuroCom Data Range: 20-39

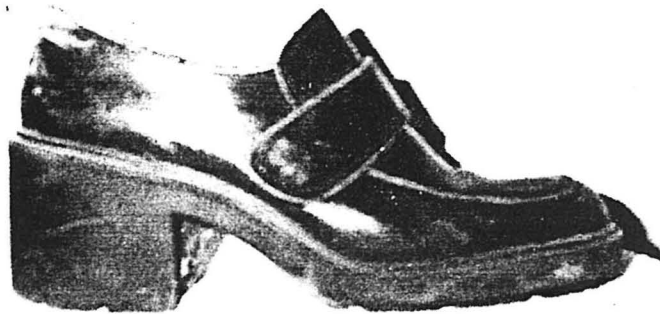
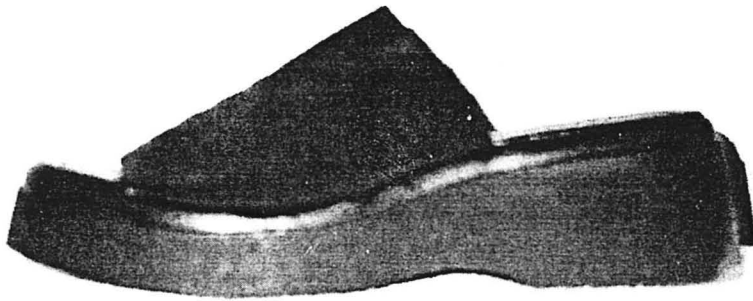
Post Test Comments:

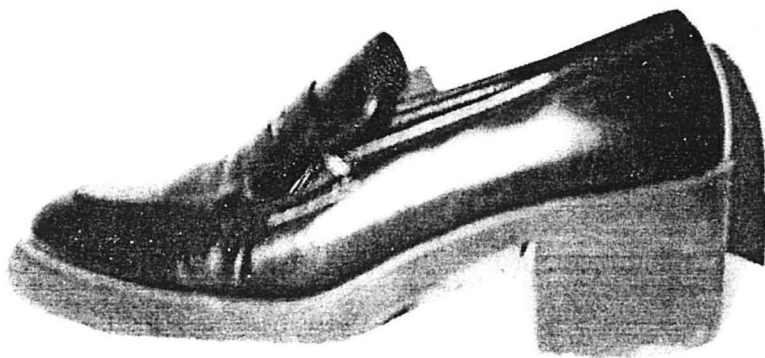
shoes on

APPENDIX E

Examples of Elevated Shoes







APPENDIX F

NeuroCom® Balance Master Verbal Instructions

Limits of stability test:

- When we start the testing, I want you to stand with both of your feet planted on the Balance Master.
- It is O.K. to lift your toes, bend at the knees, move your arms, and move your hips, as long as the base of your feet stays planted and does not move.
- When we start, I want you to keep the little man figure in the center square as steady as you can until a green GO appears at the bottom of the screen.
- You should then lean to try and move the man figure to the highlighted target with the blue circle, as quickly and accurately as possible.
- Hold it there as long as the blue circle remains, which will be for 8 seconds.
- Don't worry if you can't get all the way to the target, just get as close as you can.
- Once the cursor disappears, return to the center square and we'll start the next trial.

Bilateral stance test:

- I want you to stand with both of you feet planted on the Balance Master.
- Stand as upright and steady as you can with your eyes open looking straight ahead.
- Please do not talk or move during the testing.
- The test will last for ten seconds and we will do three trials
- Ready, set, and GO.

APPENDIX G

Functional Reach Test Verbal Instructions

- Please stand with your dominant arm closest to the wall and as close to the wall as possible (i.e. ~3 inches) without touching the wall
- Please stand with your toes (or front edge of shoes) at the edge of the line of tape on the floor with your feet at shoulder's width apart
- Stand up nice and tall and raise your arm (i.e. dominant arm) to 90° so that your arm is parallel with the measuring stick mounted on the wall
- Please make a fist with your hand (i.e. dominant arm) and reach as far forward as possible without losing your balance or taking a step
- Do not lift your heels off of the floor or twist your body when reaching, but you may bend at the hip
- Try to keep your reaching arm parallel with the measuring stick mounted on the wall, but do not touch the wall

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